Gulf of Mexico Alliance
Nutrient Sources, Fate, & Transport Study Design Workshop
February 19-21, 2008

Discussion Paper

I. EXECUTIVE SUMMARY

A common problem in the Gulf of Mexico region is excessive nutrients in coastal waters. The States participating in the Gulf of Mexico Alliance (GOMA) are each charged by the U.S. Environmental Protection Agency with establishing nutrient criteria for coastal waters to address this problem. The GOMA intends to design a common monitoring framework to provide the information needed to understand the transport, fate, and effects of nutrients and inform the process of developing nutrient criteria. The following goals will guide development of the monitoring framework:

- Standardize a regional approach that can be used at locations around the Gulf of Mexico, in a range of conditions and types of coastal waters. This design should be able to accommodate modifications that build on the core design to address local conditions and local program needs;
- Provide improved ecological understanding and identification of the core monitoring needed to characterize and understand nutrient sources, fate, transport, and effects;
- Provide sufficient understanding of water quality, circulation, and biological communities to support development of appropriate nutrient criteria for the studied systems;
- Optimize the monitoring design to the minimum necessary to determine nutrient effects and establish nutrient criteria for other parts of the coastal Gulf of Mexico; and
- Provide a sampling design for establishing long-term monitoring sites, parameters, and methodology.

Detailed study questions will also be developed to aid in the selection of ecological endpoints that best describe key effects of nutrient enrichment and to help focus ecosystem assessment and comparison among similar types of systems in the Gulf of Mexico region. Ecological endpoints will be selected to best represent biological components of Gulf ecosystems that are sensitive to changes in nutrient levels and for which a cause and response relationship can be described.

The monitoring framework will include consideration of the four major compartments that form sources or sinks of the nutrients and the fluxes of nutrients between them. These compartments are: atmosphere, biomass, water column, and sediment. Six parameters of concern have been identified: water quality, sediment quality, food web, physical and meteorological, loading, and phytoplankton.

A human use assessment will be conducted to provide critical data to understand nutrient dynamics and focus on direct measures of nutrient inputs and fluxes concentrate on the magnitude of inputs to the system, dominant transport mechanisms, and dominant chemical composition of nutrient inputs. In addition, data will be collected on human uses of the system that are affected by excess nutrients.

Because the fate and transport of nutrients in coastal ecosystems are affected by both aquatic and terrestrial components, a watershed assessment will also be conducted. Information on habitat, including distribution, extent, composition, and connectivity is important to characterize key factors that affect nutrient dynamics and the biological communities that affect nutrient dynamics.

Nutrient dynamics will be assessed through monitoring and modeling techniques to assess nutrient loading, nutrient fluxes and fate, and biological responses. To monitor the fate of nitrogen in estuaries, there are four objectives to be achieved. First, the dissolved nitrogen source should be connected to the hydrologic cycle. Second, the effects of nitrogen on the metabolic instability of the ecosystem should be determined. Third, the effects of land use on the higher trophic levels of the ecosystem should be detected. Fourth, the incorporation of nitrogen into the estuarine living resources should be traced from primary producers to top predators. In addition, the monitoring framework will plan for monitoring data needed to setup, calibrate, and validate models that will be used to inform the monitoring approach, optimize the sampling approach, and help understand the links between nutrients, water quality, and biological responses.

A sampling design is proposed as a strawman from which to develop a working blueprint for what is needed to assess nutrient related water quality conditions and trends and effects on biota in Gulf of Mexico coastal waters and their tributaries. Resource components included in the design are estuaries, near shore marine waters (out to about 3 nautical miles), and adjacent offshore waters out to beyond the influence of coastal input where background conditions exist (out to approximately the 30-m isobath). The design also monitors rivers that flow directly into estuaries, coastal marine waters, and rivers draining upland watersheds that are tributary to these waters, because fluxes of nutrients from these rivers are typically the dominant source of nutrients to coastal waters. Atmospheric deposition near the coasts will be included as will ground water in those areas where aquifers discharge directly to coastal waters. Data from the proposed design will make a significant contribution to local evaluation of the effectiveness of management actions, identification of problems, and other objectives. In combination with studies in other locations around the Gulf that follow the same core design, data will also provide information toward a Gulf-wide evaluation of the minimum necessary monitoring necessary to develop coastal nutrient criteria.

A Quality Assurance Project Plan (QAPP) will be developed to document planning, implementation, and assessment procedures and how specific quality assurance and quality control activities will be applied during a particular project. The QAPP will be composed of standardized, recognizable elements covering the entire project from planning, through implementation, to assessment.

II. INTRODUCTION

A common problem in the Gulf of Mexico region is excessive nutrients in coastal waters. The States participating in the Gulf of Mexico Alliance (GOMA) are each charged by the U.S. Environmental Protection Agency with establishing nutrient criteria for coastal waters. The GOMA intends to design a common monitoring framework to provide the information needed to understand the transport, fate, and effects of nutrients. This approach will assess nutrients and associated water quality factors as they are carried from coastal drainages through estuaries and nearshore waters into the offshore of the Gulf of Mexico.

The following are the primary goals for the monitoring design framework:

- Standardize a regional approach that can be used at locations around the Gulf of Mexico, in a range of conditions and types of coastal waters. This design should be able to accommodate modifications that build on the core design to address local conditions and local program needs;
- Provide improved ecological understanding and identification of the core monitoring needed to characterize and understand nutrient sources, fate, transport, and effects;
- Provide sufficient understanding of water quality, circulation, and biological communities to support development of appropriate nutrient criteria for the studied systems;
- Optimize the monitoring design to the minimum necessary to determine nutrient effects and establish nutrient criteria for other parts of the coastal Gulf of Mexico; and
- Provide a sampling design for establishing long-term monitoring sites, parameters, and methodology.

III. STUDY QUESTIONS

The following study questions will guide development of the core monitoring framework, selection of ecological endpoints that best describe key effects of nutrient enrichment, and help focus ecosystem assessment and comparison among similar types of systems in the Gulf of Mexico region.

1. What are the nutrient loads per unit of area, per unit of time, and per system?
2. What is the portioning among source categories and system components?
3. What are the transfer rates between system components?
4. What parts of the system components act as nutrient sinks?
5. What ecological endpoints are most sensitive to nutrient inputs?
6. What is the spatial and temporal distribution of ecological endpoints?
7. What are the trends and thresholds of significant change for ecological endpoints?
8. What mechanisms control the abundance and distribution of ecological endpoints?

Once ecological endpoints have been selected, questions specific to each endpoint will be developed. The following issues have been developed for phytoplankton, a key ecological endpoint for understanding nutrient dynamics.

Phytoplankton:

1. Refine understanding of chlorophyll *a* – nitrogen load relationship for refining chlorophyll *a* target levels for the water column.
2. Relate chlorophyll *a* to phytoplankton community composition through taxonomic and accessory pigment analyses.
3. Examine shifts in limiting nutrients through limiting nutrient bioassays with natural phytoplankton populations.
4. Propose a phytoplankton community composition metric as a management tool for ensuring efficient transfer of energy through the food web, as a tool for preventing 'dead zone' creation through excessive organic matter loading to the benthos, and as a first warning or sentinel indicator.
5. Establish relationships between traditional water quality measures and optical measures, enabling reconstruction of historical light environment.
6. Refine our understanding and application of existing light targets for seagrass recovery.
7. Propose modification to existing monitoring programs to allow for airborne/satellite monitoring of water and habitat quality and change over time.

IV. ECOLOGICAL ENDPOINTS

Meaningful regulation of nutrients requires an understanding of the effects of different nutrient concentrations on biological communities in the waters being managed. Identifying key ecological endpoints allows assessment efforts to be focused on a subset of the community, thereby minimizing the cost of collecting information while being protective of the full community.

Ecological endpoints will be selected to best represent biological components that are sensitive to changes in nutrient levels and for which a cause and response relationship can be described. The establishment of predictive and quantitative relationships between nutrient levels and ecological endpoints is important in the development of nutrient criteria.

The following table provides an overview of potential endpoints. Each endpoint will be considered in the monitoring framework and evaluated by the frequency of occurrence, duration of the associated conditions, and the area affected or covered.

Overview of Potential Endpoints:

Endpoint	Frequency	Duration	Area
Phytoplankton	Annual average concentration, growing season average, or 90th percentile.	Length of time concentration exceeds threshold levels annually and seasonally.	Percent of estuary area
Hypoxia/anoxia	Number of times a year dissolved oxygen falls to anoxic or hypoxic levels	Average and maximum length of time for which dissolved oxygen remains at anoxic or hypoxic levels	Extent of hypoxic and anoxic conditions; depth of conditions in water column
Submerged Aquatic Vegetation (SAV)	Percent of waters supporting SAV; percent of waters suitable for SAV with SAV present.	Average and maximum length of time waters supporting SAV exceed a range of water quality conditions	Extent of vegetation, density of area covered; depth of water supporting SAV
Shellfish	Percent of waters supporting shellfish species; number of times a year shellfish harvest is restricted due to water quality degradation	Average and maximum length of time shellfish waters exceed a range of nutrient levels and harvest restriction are in place	Extent of shellfish; percent of harvestable shellfish area
Harmful Algal Blooms (HAB)	Percent of waters in which HAB are detected at or above threshold levels; number of times a year HAB are detected at or above threshold levels	Average and maximum length of time HAB are detected at or above threshold levels	Average and maximum extent of blooms detected at or above threshold levels
Aesthetics- Water Clarity	Percent of waters by depth ranges for each clarity category	Average and maximum length of time during both the growing season and non-growing season for clarity categories	Depth of water by clarity categories

The following data will be collected and evaluated for their applicability as ecological endpoints:

- Nutrient Load
- Nutrient Partitioning (water column, sediment, biota)
- Nutrient Flux: transfer rate among components
- Productivity: production to respiration ration
- Fisheries productivity
- Species diversity

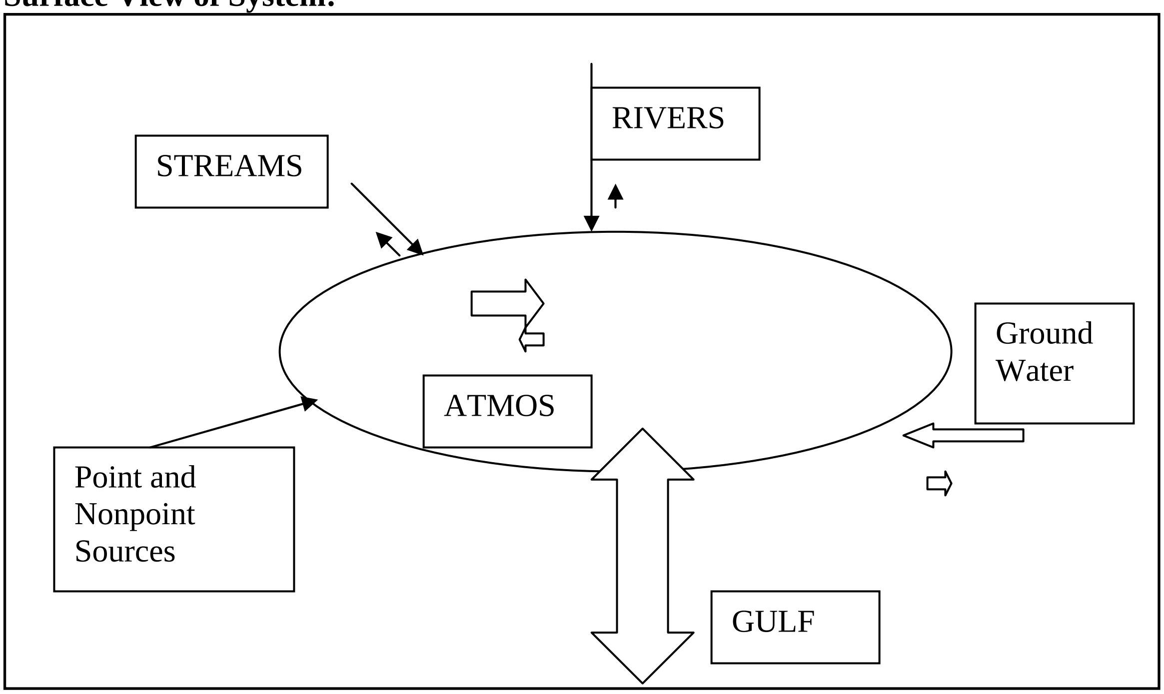
V. WHAT TO MEASURE?

The monitoring plan will include consideration of the four major compartments that form sources or sinks of the nutrients and the fluxes of nutrients between them. These compartments are: atmosphere, biomass, water column, and sediment. The water column compartment includes interactions of the estuary, bay, or other water body of concern with the oceanic Gulf waters, surface water from rivers, streams and other land runoff, and rainwater. The sediment compartment consists of the porewater.

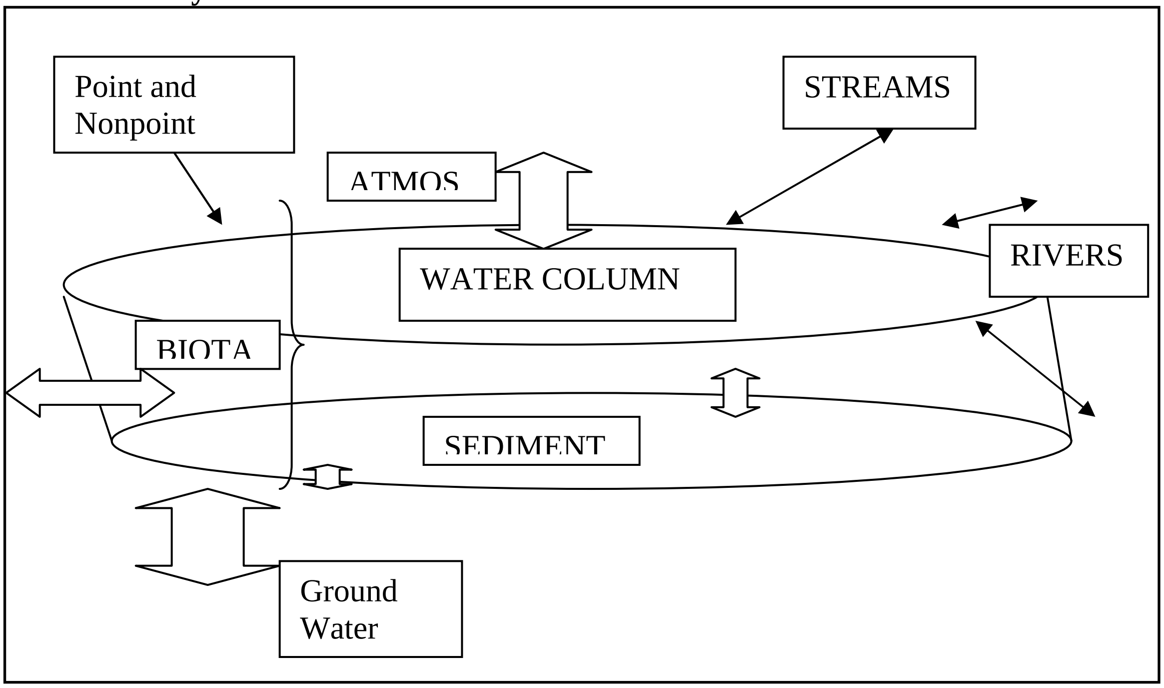
The parameters of concern fall into six categories: water quality, sediment quality, food web, physical and meteorological, loading, and phytoplankton. The parameters for each of these categories that might be measured as part of this plan are listed below.

A. Nutrient-inputs conceptual model

Surface View of System:



3-D View of System:



B. Water Quality

The parameters in the water quality category apply to surface water, ground water, the water column of the body of concern, and as practical rainwater and other atmospheric depositions. The sampling plan should be designed to determine the spatial and temporal distributions and trends and variability for each parameter. Comparisons between shallow and relatively deep waters and between nearshore and offshore water should be undertaken.

Physical and Chemical Measures of Water Quality

The following measures will be used to characterize physical and chemical trends, spatial distribution, and temporal variability for water quality:

Salinity	(conductivity)
pH	(alkalinity)
Dissolve Oxygen	(anoxia, hypoxia)
Temperature	
Clarity	(Secchi, turbidity, TSS, k_d)
CDOM	(load)
Biological Oxygen Demand	(CBOD)
Total Organic Carbon	(biomass)
Total Nitrogen	(NO_3-NO_2, TKN, NH_3) [urea]
Dissolved Organic Nitrogen	
Dissolved Inorganic Nitrogen	(load)
Total Phosphorus	(OP)

Dissolved Organic Phosphorus
Dissolved Inorganic Phosphorus
Silica

Biological Measures of Water Quality

The following measures will be used to characterize trends, spatial distribution, and temporal variability for biological measures of water quality.

Chlorophyll *a*	(spectro, fluoro, HPLC)
Phytoplankton	(Taxonomy, CHEMTAX, COA, richness/diversity)

Center of abundance (COA), taxonomy, richness/diversity (biomass):

Zooplankton
Nekton
Seston
Macroinverts

C. Sediment Quality

The parameters in the sediment quality category should be measured in the porewaters of the sediments to determine their contribution to the flux of nutrients into the water body of concern.

Nutrients	(mass, flux)
Sediment Oxygen Demand	(rate)
Redox discontinuity depth	(distribution)
% silt/clay	(distribution)
Total Organic Carbon	(mass)
Phytopigments	(mass)
Cores	(isotopes & markers)
Productivity:Respiration	(rate, distribution)
Bioassay	(limiting nutrients, light)

D. Food Web

A food web is a diagram of feeding relationships between plants and animals in an area. Rather than diagram all species, the food web is used to represent relationships between species that best represent key trophic levels. In considering the food web category, there are four isotopes that should be measured for each of the listed components. These are Carbon, Nitrogen, Sulfur, and Oxygen.

Isotopes	C, N, S, O	
	Vascular plants (aquatic and terrestrial) Algae (macro and benthic micro-) Phytoplankton Zooplankton Nekton Macroinvertebrates Particulate Organic Matter (POM) Dissolved Organic Matter (DOM)	

E. Meteorological

The meteorological parameters are necessary to characterize the light conditions of the waterbody that affect the biota and to quantify the atmospheric deposition of water (rainfall).

Rainfall	(rate + distribution)	(NEXRAD)
Irradiance	(PAR, spectral distribution)	
Water leaving radiance	(spectral)	
Backscatter	(AC-9)	

F. Physical

The physical parameters are necessary to determine transport mechanisms and to provide inputs to numerical models that might be used to forecast nutrient fluxes. The physical distributions of the biological parameters listed should be estimated as these are both sources (through decay) and sinks (through nutrient utilization) of nutrients.

Physical characteristics of ecosystems can attenuate or exacerbate the effects of nutrient enrichment. Physical characteristics also affect the types and distribution of biological communities that participate in nutrient cycling and that are also potentially at risk to nutrient caused impacts. Relationships between physical characteristics and key ecosystem responses can help define drivers and a system's susceptibility to nutrient related impairments.

Wind	
Waves	(tides)
Bathymetry	
Flow	(velocity, residence time)

The seasonal cycle of circulation on the Texas-Louisiana shelf is an example of how physical parameters may affect nearshore nutrients. In the nonsummer (generally September-May), the winds cause the river discharge from the Mississippi-Atchafalaya River system to be transported downcoast towards Mexico. In summer (generally June-August), the winds cause a current reversal that results in the pooling of the M-A river influenced waters over the Louisiana shelf. It is uncertain how this affects the nearshore environment, but it certainly contributes to the summertime hypoxia problem in Louisiana and sometimes Texas waters as shallow as 5 m, which routinely have been measured.

G. Nutrient Loading

Nutrient loading is the quantity of nutrients entering a system in a given period of time. In addition, it is important to characterize nutrient loading seasonally. Seasonal variability in loading can lead to a redistribution of nutrients or a change in nutrient fluxes among compartments and within the system that are important management considerations.

Land use	Event Mean Concentration EMC
Hydrography	(National Hydrography Dataset + bathymetry)
River & stream gauging	(tidal + non-tidal)
Nutrient Exchange Rates	(Groundwater, Atmosphere, Sediment, Biotic)

H. Phytoplankton

Phytoplankton response to nutrients is a proxy for water quality and habitat management. Water quality and optical measures allow evaluation of historical light environments.

Chlorophyll *a* is currently used as a management tool based upon an empirical relationship between chlorophyll *a*, nitrogen and phosphorus loading and light attenuation. Maintaining chlorophyll *a* target levels was presumed to allow for sufficient light penetration to support seagrass coverage, which can be an appropriate integrator of system responses to changing water quality conditions. Currently, some areas do not seem to be responding as anticipated based upon meeting these target water column chlorophyll *a* levels. Refinement of this tool is therefore needed to continue best management and will be accomplished along two lines through better understanding of phytoplankton community composition responses to nutrient loads and by establishing correlations between traditional water quality measures and optical measurements of the water column.

Chlorophyll *a* is a pigment common to all phytoplankton; measures of accessory photosynthetic pigments unique to specific functional groups of phytoplankton will allow refinement of the understanding of phytoplankton community responses to nutrients and refinement of the application of water column chlorophyll as a management tool. Better understanding of spatial (both horizontal and vertical) and temporal patterns of phytoplankton community responses to freshwater inflows and nutrient loading will allow integration of this biological response into existing management schemes and will allow application over the appropriate scale taking into account areas where depth stratification is important.

Changes in limiting nutrients can be related spatially and temporally to community composition and water column light environment. The importance of various algal groups as food for benthic organisms and fishes could then be integrated into a phytoplankton management scheme for the body of water of concern that goes beyond what a single indicator (*e.g*., chlorophyll *a*) will be able to provide. A management tool that will allow for efficient transfer of biomass through the food web by maintaining an appropriate balance of phytoplankton community populations will further help to avoid the creation of 'dead zones' due to organic matter deposition to environments where only microbial decomposition occurs rather than transfer through macroinvertebrates to higher trophic levels.

Optical properties of water (*e.g.*, transmittance), particularly as influenced by phytoplankton, turbidity, Secchi depth and colored dissolved organic matter, will be related to traditional water quality data by measuring these optical properties continuously along transects (with both vertical and horizontal components) between long-term sampling stations. Relationships between these optical and traditional measures will allow estimation of historical light environments for benthic habitats and allow refinement of existing targets and goals for seagrass recovery. These relationships will also help to better understand changes in water quality over time as they relate to historical management activities and the changing light environment available to benthic habitats.

Refinement of the spectral information generated for monitoring purposes will assist in development of airborne tools for managing water quality and benthic habitat, as well as defining spatial and temporal constraints on such applications. With this information it will be possible to define a combined fixed station, flow-through and airborne assessment protocol that will enable more cost-effective and system-wide assessment of water column and benthic habitat changes over time and space. Ultimately, this information can be used to implement a satellite-based water column and habitat quality management tool for estuarine and coastal waters of the Gulf of Mexico. Phytoplankton monitoring should consider the following:

- Perform taxonomic and HPLC analyses in conjunction with ambient nutrient sampling and speciation.
- Refine relationship between nutrient form, concentration and load with phytoplankton community composition.
- Define a monitoring program utilizing phytoplankton community responses to nutrient loading.
- Examine relations between chlorophyll *a*, accessory pigments and phytoplankton community composition.
- Propose refinement of chlorophyll *a* target levels.
- Perform limiting nutrient bioassays utilizing multiple nutrient species.
- Determine if there are spatial-temporal and/or community relationships with limiting nutrient responses.
- Refine routine sampling to ensure appropriate data is collected to monitor trends in time and space of phytoplankton community responses to nutrient loads.
- Evaluate trophic transfers as they relate to phytoplankton community composition.
- Integrate a measure of production into water quality management schemes.
- Refine monitoring programs to ensure data collection to continue this type of evaluation into the future.

- Measure optical water quality parameters, in conjunction with traditional water quality measures.
- Establish relationships between optical water quality measures and traditional water quality measures.
- Develop conceptual historical light environment based on applying optical relationships with traditional, historical water quality data.
- Calculate spectral distribution of light energy reaching benthic habitats under various conditions.
- Refine light targets for seagrass recovery taking into account observed relationships.
- Refine monitoring programs to ensure continued generation of data required to effectively manage the benthic light environment.
- Extrapolate flow-through and fixed station data to integrate water quality estimates across the bay.
- Propose minimum data requirements for establishing an operational airborne water quality and habitat monitoring program for the bay.
- Propose minimum data requirements for establishing a satellite-based water quality and habitat monitoring program for the bay.

Phytoplankton experiments that examine responses to nutrients similar to the approach described below may provide useful information. A fixed suite of parameters could be characterized for each station prior to bioassays, including bacterial abundance, phytoplankton community composition, size-fractioned chlorophyll and accessory pigments. Bioassay experiments would be conducted using N, P, and N+P combined additions as well as a control. The level of N and P additions could be determined based upon the ambient nutrient concentration in the regions and will be comparable to a bolus of nutrients found in the environment associated with a rain event. The preferred frequency of bioassays is every other month with the potential to sample two additional events annually. Duplicate bioassays of each of the four treatments would be set up using water from each site. Incubations are conducted in “cubitainers” at ambient field temperature and light intensities. A 48 hr time period is used to determine change in size fractionated chlorophyll *a* content as a result of nutrient additions.

Biomass can be used as an indicator to determine which nutrient additions from each site are being utilized. Response of the phytoplankton communities to the nutrient additions can be quantified based on changes in size-fractionated chlorophyll *a* and phytoplankton community composition using concurrent pigment analyses, microscopic analysis (identification and cell counts), and bacterial enumerations. These data will thus allow us to determine the extent to which different components of the biota responds to nutrient additions, which nutrient they are using, and whether all biotic components are responding to the same or different nutrients.

Phylogenetic-group composition can be characterized using chemosystematic (photopigment) enumeration *via* high performance liquid chromatography (HPLC). Briefly, extracted pigments (in 100% acetone) will be injected directly into a Waters 600E HPLC equipped with a monomeric and polymeric reverse-phase C_{18} columns in series and an in-line, Waters 2996 photodiode array (400-700 nm) detector. Mobile phases, solvent flow rates, and temperature regimes will follow that described by Pinckney *et al*. 1996. This methodology provides excellent resolution of ‘marker’ carotenoids and chlorophylls necessary for chemosystematic characterization of estuarine and coastal microalgal groups. Pigments will be quantified by integrating chromatographic peaks and calibrated from authentic standards. The absolute and relative chlorophyll *a* concentrations of microalgal phylogenetic groups will be derived from photopigment suites by CHEMTAX matrix factorization.

Optical measurements can be collected in real-time using a suite of sensors that have been used extensively to characterize the light fields in estuarine and coastal systems throughout Florida and the Gulf of Mexico. The optical package was developed in the Ocean Optics Laboratory at the University of South Florida (USF). The following optical parameters would be measured: percent transmittance, chlorophyll fluorescence, remote sensing reflectance, phytoplankton absorption, color absorption, scatter, backscatter, and others. Monthly data would be collected at existing fixed stations together with traditional optical (PAR and Secchi disk) and water quality measurements so that direct comparisons can be made. Every quarter, real-time optical measurements could be collected to provide a synoptic picture of the light environment by "connecting the dots" between existing fixed stations. Using the relationships between the light field and water quality, a detailed history of the light field could be reconstructed using historical data from those fixed stations that date back over ten or more years.

VI. CLASSIFICATION AND REFERENCE CONDITIONS

A. Classification of Study Areas

The NOAA Coastal and Marine Ecological Classification Standard (CMECS) provides a framework to classify coastal and marine waters and potential reference areas throughout the region. Broadly, the framework applies to nearshore coastal waters and estuarine systems. Nearshore coastal waters may be truly marine in character (> 30 psu throughout the year) or freshwater influenced (marine waters are periodically diluted by freshwater flow that originates from land) and extend from the land margin to approximately the 30 m depth contour. CMECS was created to provide ecological classifications; however where possible, nutrient classifications that result from this study should remain compatible with this system.

Freshwater-influenced systems are waters that have no distinctly enclosing morphology, yet receive a significant amount of freshwater input from land during at least part of the year. In such cases, an unenclosed marine water column may be influenced by freshwater in the form of an active river plume, an overlying freshwater lens or a ground water seep discharge. The freshwater-influenced system can occur in nearshore, neritic or oceanic depths, provided the region is influenced by freshwater input that reduces salinity to below 30 psu.

Estuarine systems consist of tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed, or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by freshwater runoff from the land. The salinity may be periodically increased above that of the open ocean by evaporation. The estuarine system extends between (1) an upstream and landward point to where ocean-derived salts measure less than 0.5 psu during the period of average annual low flow; and (2) an imaginary line closing the mouth of the river, estuary, bay, or sound.

For mapping purposes, the CMECS framework classifies coastal and marine waters by system, subsystem (subtidal, intertidal), cover (colonized or bare), class (e.g., aquatic bed) and subclass. CMECS further classifies these waters ecologically by group, biotope complex and biotope. These ecological units are uniquely associated with a given habitat type which results from a combination of the higher hierarchical levels

B. Reference Conditions Criteria

Reference conditions can be developed using areas of least human impacts that protect beneficial uses. Reference conditions can provide important information about natural background conditions, natural variability and fluctuations of ecological endpoints, as well as assist in the development of system models. The role of reference conditions in the development of nutrient criteria will be better defined as a result of these studies and evaluation of nutrient-based classes for the Gulf of Mexico region. Therefore, the following should be considered as part of the monitoring framework to collect data needed to determine factors that would allow classification based on nutrient management needs.

Spatial:	nearby similar
Historical:	archived water quality/loading data and trends modeled conditions sediment cores
Specific time:	hold-the-line strategy; known time of ‘acceptable’ conditions
Replication:	multiple sites; key protected areas such as National Estuarine Research Reserves and National Parks

VII. HUMAN USE ASSESSMENT

The human use assessment will not quantify nutrients from human sources, which would be done as part of a Total Maximum Daily Load process. Instead the assessment will concentrate on the magnitude of inputs to the system, dominant transport mechanisms, and dominant chemical composition of nutrient inputs. In addition, data will be collected on human uses of the system that are affected by excess nutrients. The assessment will provide critical data to understand nutrient dynamics and focus on direct measures of nutrient inputs and fluxes.

Human Use Data to Be Collected

Broad land use categories and pathways for nutrient sources
Point sources input

Current & historical:
Hydrography: National Hydrography Dataset, topography, bathometry

Land Use: consistent Gulf-wide categorization scheme or equivalent
Event Mean Concentration (EMC) compilation for region

Active Use: commercial – fisheries + industry
Recreational Use: boating, fishing, swimming, nature watching
Passive Use: aesthetic/spiritual/sense-of-place

Human Use Endpoints

Percent of watershed area within main categories of nutrient sources
Land cover

VIII. WATERSHED ASSESSMENT

The fate and transport of nutrients in coastal ecosystems are affected by both aquatic and terrestrial components of the watershed. Information on habitat, including distribution, extent, composition, and connectivity is important to characterize key factors that affect nutrient dynamics and the biological communities that affect nutrient dynamics. In addition, community information is important to characterize fate and associated impacts and defining the habitat and communities of interest will aid in the selection of boundaries for the study design.

Watershed boundaries will be identified using NOAA boundaries for coastal watersheds and key site information. The Meterological and Physical section above provides additional references for watershed data

Watershed Data to be Collected

- Rainfall (nutrient concentration)
- Temperature
- Wind/tides
- Slope
- Hydric soils acreage
- Erodible soils acreage
- Freshwater flow - peak, wet-weather, dry-weather, baseline
- Groundwater flow
- Residence time/flushing rate
- Offshore to inshore: chemical, physical, and biological variables
- Residence time/flushing rate
- Key Species abundance, distribution, and health
  - Shrimp
  - Fish
- Key Communities abundance, distribution, and health
  - Benthic community
  - Macroinvertebrate community
  - Riparian habitat

Wetland habitat
Submerged aquatic vegetation (SAV) community
Shellfish beds
Harmful Algal Blooms (HAB) occurrence and origination
Hypoxia occurrence
Impervious surface area

Watershed Endpoints
To be added

IX. NUTRIENT LOADS AND MODELS

Nutrients enter coastal ecosystems from terrestrial, freshwater, and marine sources.

A. Nutrient Loading

The CHRP (Coastal Hypoxia Research Program) is currently funding an examination of coastal estuaries within the Gulf of Mexico with three major components: modeling watershed nutrient fluxes, modeling the nutrient and oxygen responses in estuaries, and evaluating the ecological consequences. The U.S. Geologic Service (USGS) SPARROW modeling framework can be used to examine nutrient loadings in the major Gulf estuaries, including one along the Texas coast. This approach will allow for better predictive understanding of the potential causes and consequences of nutrient pollution on estuarine ecosystems and how estuarine hydrology and morphology modulate estuarine and upper trophic level responses.

In addition, a basin-wide SPARROW model has been developed for the Mississippi River watershed and regional SPARROW models are in development for the lower Mississippi River watershed to quantify annual nutrient loadings, as well as the timing. The developing SPARROW models will also feature improved estimates of nutrient loads from major point sources.

B. Mass Balance- input, output, and storage

Refined loading estimates from SPARROW modeling complements ongoing efforts to improve modeling of the fate and transport of nutrients in relation to the hypoxic zone in the northern Gulf. These models integrate oceanographic physical data, including those based on a ROMs framework, and coastal biogeochemistry to improve quantification of the duration, timing, and extent of the hypoxic zone, and their relationship to causative factors such as nutrients and stratification. Models addressing the hypoxic zone include a mixture of simple and complex (e.g. 3-dimensional) types, as well as empirical and mechanistic models.

The CHRP modeling effort should be expanded to include additional estuaries and reduce existing uncertainty of estuarine responses to nutrient inputs. The current modeling framework utilized for the hypoxic zone should be expanded to additional areas of the Gulf coast, especially Texas where an extensive hypoxic ZONE formed at the mouth of the Brazos River in 2007. These additional coastal models should reflect the similar mixture utilized for the hypoxic zone (i.e., simple versus complex and empirical versus mechanistic). Data derived from this proposal will also augment existing modeling efforts with the goal of reducing uncertainty in the transport, fate, and impact of nutrients in estuaries and coastal waters of the Gulf.

C. Nutrient Fate

To monitor the fate of nitrogen in estuaries, there are four objectives to be achieved. First, the dissolved nitrogen source should be connected to the hydrologic cycle. Second, the effects of nitrogen on the metabolic instability of the ecosystem should be determined. Third, the effects of land use on the higher trophic levels of the ecosystem should be detected. Fourth, the incorporation of nitrogen into the estuarine living resources should be traced from primary producers to top predators. This fourth objective is most difficult to achieve and so may be optional. Required measurements and methods for each objective are given below

1. Dissolved N and P source and hydrologic connectivity

Required measurements:

- Species-specific N and C concentrations (standard methods)
- 13C, 15N, 18O of DIC and nitrate (benchtop isolation chemistry, mass spec)
- Streamflow (gage)

Isotopic signatures allow identification of land use/cover sources that contribute nitrogen to the estuary. 13C and 15N isotopes have broad application for identifying sources and hydrologic connectivity. Measuring both 15N and 18O in dissolved NO3 increases source discrimination capability. When combined with streamflow data, seasonal changes in hydrologic connectivity can be observed.

2. N and P effects on ecosystem metabolic instability

Method 1: Relationship between DO and CO2

Required measurements:

- Dissolved oxygen (electronic sensor)
- Dissolved CO2

Calculated from:

- pH (electrode)
- temperature (thermistor)
- alkalinity (benchtop probe)

Strong positive relationship between DO and CO_2 indicates ecosystem P:R instability and associated increased chance of hypoxia

Method 2: 18O enrichment
Required measurement:
Dissolved oxygen 18O (GC/mass spec)

Photosynthesis does not fractionate ambient oxygen. Plant and animal respiration favors use of 16O, causing enrichment of 18O in water. When community respiration rates are relatively high (low P:R), dissolved oxygen becomes enriched in 18O. Low P:R (enriched 18O) is an indicator of increased hypoxia risk. 18O is a relatively new proxy for P:R, and can be compared with the DO vs. CO_2 method above.

Note: P:R undergoes a daily light-dark cycle, the amplitude of which is also an indicator of hypoxia risk

3. Detecting land-use effects on higher trophic levels

N isotope mixing models are needed for striped mullet or other primary consumers (e.g., bivalves)

Required measurements:
Animal tissue 15N (mass spec, fin clips may be used)
GIS land use/cover in the watershed

Models for striped mullet work very well in west-central Florida estuaries (12 estuarine areas, $r^2 = 0.89$ for predicted vs. observed fish tissue isotopes). The models require good hydrologic connectivity with the watershed. Effects of low hydrologic connectivity conditions are currently being modeled. Fitted numerical coefficients are a potentially powerful tool for evaluating both the connectivity and bioavailability (fate) of N from different land use/covers. Results from Objective 1 enhance model performance.

4. Optional - Tracing N incorporation into estuarine living resources; from primary producers to top predators

Required measurements:
13C, 15N, 34S from:
POM (filtrations, mass spec)
benthic microalgae (grab samples or samples grown in situ, mass spec)
vascular plants (leaf samples, mass spec)
zooplankton (plankton net)
invertebrate benthos (grab samples)
bivalves, fishes (hand collection, seines, trawls, traps - fin clips may be used)
By matching N sources to biological sinks, dominant bioavailable N sources can be identified. Discrimination capability is enhanced by using multiple stable isotopes

D. Modeling

It is important to plan for monitoring data needed to setup, calibrate, and validate models that will be used in the study. Models can also be used to inform the monitoring approach, optimize the sampling approach, and help understand the links between nutrients, water quality, and biological responses.

Model Needs:

Model accuracy and reliability
Nutrient assimilative capacity
Fill data gaps

X. SAMPLING DESIGN

The sampling design proposed here provides a strawman from which to develop a working blueprint for what is needed to assess nutrient related water quality conditions and trends and effects on biota in Gulf of Mexico coastal waters and their tributaries. Resource components included in the design are estuaries, near shore marine waters (out to about 3 nautical miles), and adjacent offshore waters out to beyond the influence of coastal input where background conditions exist (out to approximately the 30-m isobath). The design also monitors rivers that flow directly into estuaries, coastal marine waters, and rivers draining upland watersheds that are tributary to these waters, because fluxes of nutrients from these rivers are typically the dominant source of nutrients to coastal waters. Atmospheric deposition near the coasts will be included as will ground water in those areas where aquifers discharge directly to coastal waters. Data from the proposed design will make a significant contribution to local evaluation of the effectiveness of management actions, identification of problems, and other objectives as described in this section. In combination with studies in other locations around the Gulf that follow the same core design, data will also provide information toward a Gulf-wide evaluation of the minimum necessary monitoring necessary to develop coastal nutrient criteria.

Data from each resource component could stand alone and would be valuable for that reason alone. However, the design was constructed as a whole so that its value is greater than the sum of its parts. Several features of this integrated design are worth noting. First, the design recognizes that the environmental components are linked by the hydrologic cycle through which water is constantly moving. The quality of coastal waters as related to nutrient is determined in large part by the sources of tributary waters that carry materials including sediment, naturally-occurring and anthropogenic nutrients, and many types of organisms, which can process/alter in situ nutrients. Second, the monitoring plan has a common set of analyses that will further strengthen the linkages established by the flow of water among the resource components. Thus, the sampling design will provide insights into the onshore sources of water and nutrients, and to their effect on the coastal resources. Third several different methods of data collection are used in the design, each of which is appropriate for the scale of the specific resource component and monitoring purpose.

A. Resources to Monitor

The two primary resource compartments to be monitored are estuaries and near coastal oceans. Offshore waters must also be monitored to the extent necessary to provide end points for coastal hydrodynamic models and nutrient fate and flux models. In some cases, understanding nutrient fate may necessitate nutrient and effect monitoring beyond state waters in order to understand the mechanisms sufficiently to identify the critical points to monitor as part of reduced monitoring designs. Coastal rivers, groundwater and atmospheric deposition will also be monitored as "fluxes" rather than resource compartments.

Many of the measurements are made in all resource components but some measurements are resource specific (*e.g.* it makes no sense to measure dissolved oxygen in atmospheric deposition). This is an important aspect of the overall design because this continuity of measurements will allow linkages among the resources. For example every constituent group measured in rivers is also measured in estuaries and offshore. Where appropriate, ground water and atmospheric deposition will also be monitored for the same group of constituents. Thus, for example, it will be possible to identify at a broad scale the inland sources of nutrients and determine loads of nutrients to estuaries and the coastal ocean. Similarly, many of the constituents measured in estuaries will also be monitored in the near shore oceans to strengthen our understanding of the linkages among these marine resource components. Gathering information to allow creation of flux and load models is highly desirable.

B. General approaches to site selection

In 1997, a CENR report, "Integrating the Nation's Environmental Monitoring and Research Networks and Programs: A Proposed Framework," defined a three-level framework related to the spatial and temporal coverage of monitoring (CENR, 1997). The three levels were given as:

- inventories and remote sensing programs,
- national and regional resource surveys, and
- intensive monitoring and intensive research sites.

This design may include inventories and remote sensing, targeted monitoring and probability-based surveys, and intensive monitoring. Thus, the design takes advantage of all of the types of monitoring approaches listed above and of current technology to meet multiple objectives. Inventories provide complete spatial coverage of a resource. An inventory is a census of the entire resource at a particular point in time, such as that available from remote sensing programs. To be useful in a monitoring program, the inventory must be available in near-real time or within a few months. At the opposite end of the spectrum of spatial coverage, intensive monitoring is characterized as site-specific and is typified by either repeated measurements at a single site or the use of a large number of sites in a relatively small area. Examples of intensive monitoring include the use of moored buoys that record (and transmit in some cases) data in relatively small time steps to provide information about short term variability in water temperature.

Regional surveys are a frequently used approach. These surveys gather information at a large number of locations with a goal to describe the results at broad spatial and temporal scales. Monitoring sites for regional surveys may be selected as "targeted" or "representative" sites.

Targeted sites are necessary when information is required at specific locations or implementation can only be accomplished under special conditions. Targeted site selection applies to selection of sites using the best professional judgment of experts guided by local knowledge and design goals and objectives. Transport within individual estuaries could be monitored using this approach.

When the objective is to make inference to an entire resource, for example, all estuaries within a state or all estuaries in the Gulf of Mexico, then determining the location of “representative” sites is best accomplished by implementing a probability-based survey design. Selecting sites randomly enables a scientifically-defensible answer to such questions as “What percent (or how many hectares) of the estuarine resource in the United States have nutrient concentrations greater than a specified value?” The form of the question provides information that helps determine the number of sites required. If, for example, the percent of the resource with a specific condition must be estimated with a margin of error (confidence interval half-width) of plus or minus 12 percent and confidence of 90 percent, depending on the variability of what is being measures, then approximately 50 sites are required.

C. Data Collection Approaches

There are three basic approaches for data collection: remote sensing, continuous sampling, and discrete sampling.

- **Remote Sensing** platforms include *non in situ* measurement methods such as atmospheric-based (*i.e.*: aircraft deployed) measurements and space-based (satellite deployed) measurements. Remote sensing instruments are often categorized by the sensor's radiometric resolution, spatial resolution, and temporal resolution. The temporal resolution that can be achieved using remote sensing varies from less than an hour to several days depending on characteristics of the sensor and whether it is deployed on an aircraft or satellite. The great advantage of remote sensing is that this tool allows for an inventory of the entire resource at a particular point in time. The U.S. National Polar-orbiting Operational Environmental Satellite System (NPOESS) is an example of a new generation of satellite systems intended to address the challenges of resolution and continuity. NPOESS, the first operational satellite with an ocean color sensor, will combine infrared and microwave measurements to provide a powerful new tool for synoptic mapping of temperature discontinuities and ocean color in real time and for comparative analysis of water quality in coastal ecosystems on a global scale. Remote sensing is typically applied for continuous observation and measurement of physical variables such as water temperature, wind speed and direction, current speed, wave height, sea level, and sea ice distribution. With a few exceptions, such as ocean color and chlorophyll concentrations, most chemical and biological measurements are not amenable to remote sensing at this time, although improvements in sensing technology may allow these measurements in the future.

- **Continuous Sampling** results in multiple, evenly spaced *in situ* measurements over a time interval. This type of data is normally collected electronically (sensors with data logger) and may or may not be available in real time through cell phone or satellite communications. The collection of continuous data allows for the investigation of a system's response to short-term events (tidal cycles, weather fronts, algal blooms, etc.) and provides calibration and/or validation data for models that run with short time steps. Continuous water quality monitoring is commonly performed using in situ sensors and, increasingly, with auto analyzers. *In situ* sensors can monitor temperature, pH, dissolved oxygen, specific conductance, light spectra, currents (direction and speed), and waves. Auto analyzers can now monitor for some nutrients including total reactive phosphorus, ammonia, and nitrate. The drawbacks to continuous sampling are that sensors and auto analyzers must be visited periodically for maintenance and calibration. Parameters that cannot currently be measured with continuous sampling, but for which sensors are under development, include: plankton and many macro and micro nutrients.

- **Discrete Sampling** is the collection of individual samples, usually by an observer, which result in measurements with a larger sample interval than for continuous sampling (for example, monthly). Discrete samples may also be collected with an unequal sample interval. For example, monthly samples are typically collected on approximately the same day each month as opposed to a constant 30-day sample interval. The great advantage of discrete sampling is that the sample is typically transported to a laboratory, on shore or aboard research vessels, where it can be analyzed for a great range of chemical characteristics. The collection of discrete data can provide spatial patterns of variables. If collected at the same points, over the long-term (several years) the discrete data become an invaluable tool for identifying water quality trends and variability and developing measures for addressing ecosystem changes.

D. Summary of monitoring design

The condition of the resource will be assessed for estuaries and the near shore marine environment out to approximately the 30-m isobath. Each of these resources is also assessed using targeted sampling and remote sensing. Rivers will be monitored to determine the flow of water and loads of nutrients into estuaries. Because estuaries are the connection between fresh water flowing from land to the oceans, each estuary will also be monitored along a salinity gradient to gain insights into the transport of water and waterborne constituents. In some places, where ground water flows directly into coastal waters, that resource will be monitored. Atmospheric deposition, which can be a significant source of some nutrients will be monitored in the coastal zone. Finally, recreational beaches will be monitored for HAB related issues.

E. Sampling design for estuaries

In order to address the stated goals of the monitoring plan, targeted and probabilistic site selection may be used, as well as continuous and discrete sampling. Changes and trends over time can be detected by repeated collection of data within the individual estuaries and by re-visiting randomly-selected sites used to determine conditions of estuaries. Each of the purposes and the approach taken will be described briefly. The core study time period will be establish to ensure that variability is captured to improve ecosystem understand. It is recommended that studies will be a minimum of annual and a reduced study design will be developed for studies over 2 to 3 years to capture inter-annual variability.

Conditions Regionally: Sites may be selected probabilistically from among all estuaries, with approximately 50 total sites selected for the region. Thus, it would be possible to make statistically valid statements about the conditions of estuaries in the Gulf region compared to other regions. Comparisons between and among regions would be possible.

Conditions in Individual Estuaries: In general, the assessment of overall conditions for individual estuaries or portions thereof can employ a total of approximately 50 sites per estuary, selected using a probability-based method that will provide geographic coverage. Note that sampling sites for the estuaries extend to the head of tide in the major tributaries. The selected sites could be sampled monthly for water column nutrients and physical characteristics (conductivity, pH, dissolved oxygen, temperature). The intensive sampling of each estuary would provide managers with a statistically valid picture of overall conditions within the estuary.

Transport through estuaries: This component of estuarine monitoring will provide data to help understand the timing and flow paths for water and waterborne constituents moving from major riverine inputs through the estuary and seaward into the near shore environment. A targeted approach based on professional judgment will select a maximum of 15 sites (fewer in the smallest estuaries) located along the major salinity gradient of each of the estuaries. These sites will be sampled monthly for water column nutrients and physical characteristics (conductivity, pH, dissolved oxygen, temperature). For those locations where the average water depth is greater than 5 meters, samples will be collected at the top and bottom of the water column. Properly selected transects can provide information on: (1) processing of nutrients within the estuary, (2) export of nutrients to the coastal zone, (3) nutrient and suspended sediment loads from rivers and streams, and (4) residence time within the estuary. Existing protected estuarine sites with continuous monitoring, such as the NOAA National Estuarine Research Reserve System, could be used for transport studies.

Short-term variability: Sites in each estuary that are used for the transport component can also be instrumented for continuous monitoring of constituents such as depth, temperature, salinity, dissolved oxygen, pH, and turbidity. Other possible constituents such as chlorophyll and other plant pigments and nutrients may also be included as technology improves and these measurements become more feasible. Specific information this monitoring could provide includes (1) timing and duration of conditions like hypoxia, (2) timing and duration of freshwater pulses, and (3) effects of hurricanes and other extreme events on estuarine water quality.

F. Sampling design for near-shore coastal waters

Three different monitoring approaches will be used to address conditions in near shore waters. First, a probability based survey will allow an assessment of the resource across the region. This is similar in design to that for the condition assessment in estuaries except that an appropriate number of sites would be chosen for the coastal segment. Previous national designs have used a total of 50 sites for coastal waters. These sites would be sampled once per year or at additional frequency as required for physical conditions or water column nutrient chemistry. This sampling effort will be based on discrete samples collected from research vessels. A second, targeted, approach will also be used to assess near shore conditions. These sites could be located at fixed locations, where appropriate such as lighthouses or small islands. The frequency of data collection and the constituents to be monitored will be determined by the needs of the study design. The third approach for near shore waters is the use of remote sensing which will allow the entire resource to be assessed for those constituents (e.g. surface water chlorophyll) that can be monitored remotely.

G. Sampling design for ground water

Determining the significance of ground water to coastal water quality involves the characterization of local and regional hydrogeologic settings, hydraulic relationships between surface waters and ground water, and natural and manmade nutrient sources. Because this effort is regional in scale, the focus is on ground water resources that could be termed “major aquifers,” in relation to the potential impact on coastal resources.

Ground water monitoring is important to the design but has less detail and specificity when compared to other resources. The primary reason for the difference in treatment within the overall design is that the relative impact of ground water on coastal waters will vary by location. In some areas, ground water monitoring will be critical to understanding loads of constituents to coastal waters. In other areas, ground water will be relatively insignificant when compared to surface water; however, ground water must always be considered in the overall budget of sources of nutrients. Notable examples that demonstrate the importance of ground water to coastal water quality include the effects of nutrients on estuarine and coastal resources in Florida’s Biscayne Bay, and the impacts of water supply pumping along the Gulf Coast/Mississippi River delta area where subsidence is causing significant loss of wetlands. In addition, ground water monitoring is especially useful in areas where loadings from other sources cannot account for the measured values within an estuary.

Ground Water Resource Characteristics of Significance to Coastal Water Quality

The importance of ground water, as a contributing factor or mechanism affecting coastal surface water quality, varies spatially around the country. Overall, the importance depends primarily on the following factors:

1. The relative contribution of ground water discharge in relation to surface runoff and stream flow.
2. The direct discharge of ground water to bays and estuaries. There are several examples along the U.S. coastline where major aquifers discharge directly to coastal and estuarine waters, increasing the likelihood that ground water-borne loadings could represent a significant source of impacts.
3. The importance of site-specific conditions related to nutrient loadings. This factor represents the effectiveness of the aquifer system as a conduit for land-based contamination, in combination with the presence of natural or anthropogenic nutrients in the ground water flow system.
4. Multiple vs. single aquifer units. The country's coastline can be divided into segments with single, unconfined aquifers vs. multiple, stacked aquifers. In the Coastal Plain areas, multiple aquifer units exist, separated by confining units. Each aquifer can have different characteristics in terms of flows and nutrient loadings to the coastal waters. In particular, the deep, confined aquifer units are generally more protected from surface contamination, but they also have very long timeframes in terms of contaminant source-to-coastal discharge and thus they can act as significant long-term threats to coastal waters. The Coastal Plain formations stretch from the south coast of Long Island through Texas.
5. Presence of ground water nutrients at significant enough concentrations. While the hydraulic discharge rate in relation to surface water flows is important, the concentrations in ground water must also be considered in relation to the potential impacts of nutrient loadings in ground water discharging to coastal waters, as well as the potential for the ground water-borne nutrients to reach the coastal waters. Specifically, the fate and transport characteristics of each nutrient of potential concern help determine its threat to coastal resources. For example, nitrates generally migrate in ground water flow systems with little attenuation, whereas many phosphorus compounds are filtered via various processes.

Challenges in Designing a Ground Water Monitoring Network for Coastal Water Quality Contributions

By the examples offered above, the importance of ground water to coastal water quality has been demonstrated for at least a portion of the Gulf coastline. However, the various factors and characteristics listed above also indicate the level of complexity involved in designing a regional monitoring network component for ground water. The challenges include:

- Spatial variability and the significance of site-specific problems make it difficult to develop a generalized approach.
- Ground water aquifers have "response times" and "delivery rates" that extend over longer time periods than surface waters, extending the duration of nutrients-discharge impacts in comparison to similar-scale surface water bodies.
- Effective sampling of ground water is hampered by accessibility and representative-volume problems.

- Solving problems that involve ground water quantity and quality seems to suffer more (than equivalent surface water system-generated problems) from the lack of data, and gathering data once a problem is identified is generally more difficult and expensive.
- Historically, ground water problems predominantly revolved around quantity and hydraulics issues; thus, in general, the historic database of ground water quality information still lags that of surface water quality.

Basic Design Approach for Ground Water

With these challenges in mind, a set of recommendations has been developed to provide the basic design approach for the ground water resource component. Overall, the design approach should follow a logical, stepwise process that relies upon oversight by a nationwide group of ground water experts, and local implementation by ground water experts in each defined local ground water area.

The following overall guiding principles are recommended:

- The local ground water experts should reach a consensus on appropriate levels of monitoring in each local area to be monitored. In addition, they should provide input to the national group of experts on the areas appropriate to local studies, and on the national framework for ground water monitoring.
- Existing data collection programs should be utilized to the extent possible. Within the U.S., the National Water-Quality Assessment (NAWQA) efforts undertaken by the USGS serve as one “model” program, as well as that agency’s State Water Office implemented efforts toward long-term monitoring of ground water levels and ground water quality, tied together through national data portals on the Internet. The hallmark of these efforts is regional monitoring coverage that includes spatially distributed monitoring at appropriate frequencies for providing important ground water hydraulic, hydrologic, and water quality information.
- Overlay mapping should be conducted to identify the relative significance of ground water to coastal water quality, using maps of surface water hydrologic networks, hydrogeologic formations/aquifers, land use and population density, ground water quality, and existing coastal water quality problems related to ground water. This will help to focus the efforts of local ground water experts by identifying the coastal areas where ground water discharge and ground water-borne contamination are known to be, or are likely to be, the predominant factors in coastal water quality.
- The most pressing ground water related problems should be identified, and a list of ground water parameters to be measured should be developed, based on the identified problems. Most of the parameters will be monitored through direct sampling of ground water in drilled wells; however, the design should also incorporate innovative methods, including remote sensing and imagery. For example, the use of satellite imagery to identify temperature changes and contrasts in coastal waters could be used to indicate the relative magnitude and significance of ground water discharges.

H. Sampling Design for atmospheric deposition

The focus of the atmospheric deposition component of the Network is the deposition that falls directly on estuaries and coastal waters and the loads of substances that are present in wet and dry deposition. This monitoring of direct deposition is distinguished from the water and associated constituents that enter coastal waters through storm water runoff. At present very little is known about the importance of atmospheric loadings to coastal waters (Valigura and others, 2000); thus, the Network monitoring proposed here will make a significant contribution to our current understanding.

This effort will address the atmospheric deposition by monitoring wet and dry atmospheric deposition near the mouths of coastal HUC 6 outflows (Hydrologic Unit Code, sixth level). Actual sites will be selected by resource management agencies and other technical experts. This will provide data for estimates of direct atmospheric deposition to coastal waters. Although these sites are likely to be land based, if they are located near the coast, they will capture dry deposition that is representative of the area to be monitored and wet deposition from widespread storms. These sites will not capture the effects of localized events but this is consistent with the overall design which is focused on a larger (regional) spatial scale.

At present, the primary atmospheric deposition monitoring program is the National Atmospheric Deposition Program (NADP). The NADP is a cooperative that includes federal and state agencies, tribes, universities, industry, and non governmental organizations.

XI. QUALITY ASSURANCE PLAN

The Quality Assurance Project Plan (QAPP) should document the planning, implementation, and assessment procedures of, and how specific quality assurance (QA) and quality control (QC) activities will be applied during a particular project. It is important to understand the terminology of quality assurance and quality control in order to develop a QAPP. Key definitions include:

Precision -- the degree of agreement among repeated measurements of the same characteristic. It may be determined by calculating the standard deviation, or relative percent difference, among samples taken from the same place at the same time.

Accuracy -- measures how close your results are to a true or expected value and can be determined by comparing your analysis of a standard or reference sample to its actual value.

Representativeness -- the extent to which measurements actually represent the true environmental condition or population at the time a sample was collected.

Completeness -- the comparison between the amount of valid, or usable, data you originally planned to collect, versus how much you collected.

Comparability -- the extent to which data can be compared between sample locations or periods of time within a project, or between projects.

A. Steps to Developing a QAPP

Step 1: Establish a QAPP team
Step 2: Determine the goals and objectives of your project
Step 3: Collect background information
Step 4: Refine your project
Step 5: Design your projects sampling, analytical and data requirements
Step 6: Develop an implementation plan
Step 7: Draft your standard operating procedures (SOPs) and QAPP
Step 8: Solicit feedback on your draft SOPs and QAPP
Step 9: Revise your QAPP & submit it for final approval
Step 10: Begin your monitoring project
Step 11: Evaluate and refine your QAPP

While most QA Project Plans will describe project- or task-specific activities, there may be occasions when a generic QA Project Plan may be more appropriate. A generic QA Project Plan addresses the general, common activities of a program that are to be conducted at multiple locations or over a long period of time; for example, it may be useful for a large monitoring program that uses the same methodology at different locations. A generic QA Project Plan describes, in a single document, the information that is not site or time-specific but applies throughout the program. Application-specific information is then added to the approved QA Project Plan as that information becomes known or completely defined. A generic QA Project Plan shall be reviewed periodically to ensure that its content continues to be valid and applicable to the program over time.

The level of detail of the QA Project Plan should be based on a graded approach so that the level of detail in each QA Project Plan will vary according to the nature of the work being performed and the intended use of the data. As a result, an acceptable QA Project Plan for some environmental data operations may require a qualitative discussion of the experimental process and its objectives while others may require extensive documentation to adequately describe a complex environmental program.

B. Content Requirements

The QA Project Plan is a formal document describing in comprehensive detail the necessary QA, QC, and other technical activities that must be implemented to ensure that the results of the work performed will satisfy the stated performance criteria. The QA Project Plan must provide sufficient detail to demonstrate that:

- the project technical and quality objectives are identified and agreed upon;
- the intended measurements, data generation, or data acquisition methods are appropriate for achieving project objectives;
- assessment procedures are sufficient for confirming that data of the type and quality needed and expected are obtained; and
- any limitations on the use of the data can be identified and documented.

Most environmental data operations require the coordinated efforts of many individuals, including managers, engineers, scientists, statisticians, and others. The QA Project Plan must integrate the contributions and requirements of everyone involved into a clear, concise statement of what is to be accomplished, how it will be done, and by whom. It must provide understandable instructions to those who must implement the QA Project Plan, such as the field sampling team, the analytical laboratory, modelers, and the data reviewers. In all aspects of the QA Project Plan, the use of national consensus standards and practices are encouraged.

In order to be effective, the QA Project Plan must specify the level or degree of QA and QC activities needed for the particular environmental data operations. Because this will vary according to the purpose and type of work being done, EPA believes that the graded approach should be used in planning the work. This means that the QA and QC activities applied to a project will be commensurate with:

- the purpose of the environmental data operation (e.g., enforcement, research and development, rulemaking),
- the type of work to be done (e.g., pollutant monitoring, site characterization, risk characterization, bench level proof of concept experiments), and
- the intended use of the results (e.g., compliance determination, selection of remedial technology, development of environmental regulation).

The QA Project Plan shall be composed of standardized, recognizable elements covering the entire project from planning, through implementation, to assessment. These elements are presented in that order and have been arranged for convenience into four general groups. The four groups of elements and their intent are summarized as follows:

Project Management - The elements in this group address the basic area of project management, including the project history and objectives, roles and responsibilities of the participants, etc. These elements ensure that the project has a defined goal, that the participants understand the goal and the approach to be used, and that the planning outputs have been documented.

Data Generation and Acquisition - The elements in this group address all aspects of project design and implementation. Implementation of these elements ensure that appropriate methods for sampling, measurement and analysis, data collection or generation, data handling, and QC activities are employed and are properly documented.

Assessment and Oversight - The elements in this group address the activities for assessing the effectiveness of the implementation of the project and associated QA and QC activities. The purpose of assessment is to ensure that the QA Project Plan is implemented as prescribed.

Data Validation and Usability - The elements in this group address the QA activities that occur after the data collection or generation phase of the project is completed. Implementation of these elements ensures that the data conform to the specified criteria, thus achieving the project objectives.

All applicable elements, including the content and level of detail under each element, defined by the organization(s) sponsoring the work must be addressed in the QA Project Plan. If an element is not applicable, state this in the QA Project Plan. Documentation, such as an approved Work Plan, Standard Operating Procedures, etc., may be referenced in response to a particular required QA Project Plan element to reduce the size of the QA Project Plan. Current versions of all referenced documents must be attached to the QA Project Plan itself or be available for routine referencing when needed. The QA Project Plan shall also address related QA planning documentation (e.g., Quality Management Plans) from suppliers of services critical to the technical and quality objectives of the project or task.

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More information on the Gulf of Mexico Alliance and work by the Nutrients and Water Quality Priority Issue Teams can be found at http://www2.nos.noaa.gov/gomex/nutrients/welcome.html.

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